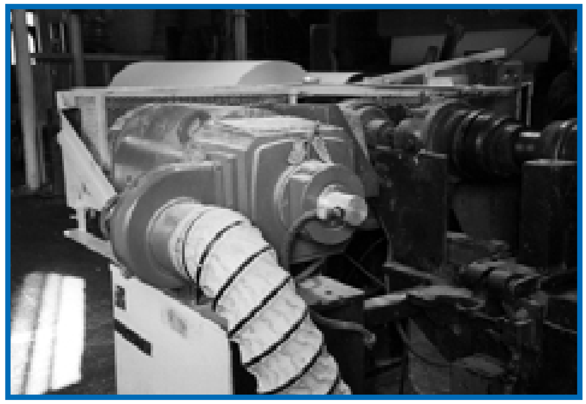
ENERGY MATTERS

March/April 2000

Putney Paper Company Becomes More Energy Efficient with Help from Green Mountain Power



Regenerative drive system on #4 rewinder.

A major rebuild of your processing plant may seem like a daunting endeavor, but Putney Paper Company did just that and is now saving energy and money. The Vermont-based paper-recycling mill upgraded many of its older motors and installed variable frequency drives (VFDs) on its pump and agitator system. The upgrade also entailed rerouting water flow, which eliminated the use of one pumping system. The project is saving the company 400,000 kWh of electricity, or $30,000 annually.

To offset costs and increase efficiency, Putney took advantage of technical assistance and rebates from its electric utility, Green Mountain Power Corporation (GMP), an OIT Allied Partner.

Using original equipment installed in the 1930s was costing Putney Paper Company a heavy price in high energy bills. In an effort to lower costs, in the early 90s, Putney learned of energy efficiency incentives offered by GMP and replaced 27 motors with high efficiency ones that meet or exceed EPAct requirements. The positive results led to further upgrades and opportunities to work with GMP on the recent major plant rebuild.

By 1997, Putney planned to rewind about 13 of the plant's motors driving the mill's pumping process. GMP's review of the plans led to the mill changing the project plan. Instead of rewinding, Putney decided to replace the motors and include upgrades to the agitator systems. "Putney was already committed to upgrading their older equipment to improve productivity. What we were able to bring were recommendations for getting the maximum possible energy savings out of the upgrades," said Dan Gaherty, Green Mountain Power Corporation. GMP provided MotorMaster+ software to help Putney analyze motor replacement options. As a result, Putney installed 15 premium efficient motors and 2 VFDs to operate its pump system. Putney also changed the routing of tray water from the paper machine. The rerouting enabled the company to shut down one pump and use gravity flow in its place, which offered more reliability and cost reductions.

Benefits

In addition to cost savings and energy efficiency, the upgrade has other benefits. For instance, the VFDs have given the operators more control of the process. "We're saving energy by using inverters [VFDs] to achieve the pumping capacity we need. We've eliminated valves and the waste associated with throttling back," said Don Sellarole, plant engineer at Putney. Without throttling back, the operating life of the pump is extended. Also, pressure adjustments have been converted to a digital mode, which allows greater precision and saves time on maintenance. The only drawback is the more complicated drive system that requires greater technical knowledge and expertise to run effectively. To address this, Putney has provided staff training in maintenance and troubleshooting.

Incentives from GMP for the two VFDs reduced payback time from 1.2 years to less than a year.

Working together, Putney Paper and GMP prove that energy efficiency, lower costs, and technological advancement can be affordable realities.

An Office of Industrial Technologies Bimonthly Publication Focusing on Energy Efficiency Opportunities for Today

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Issue Focus: Adjustable Speed Drive (ASD) Technologies

In This Issue

Insert:

Combined Heat and Power Supplement

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COMMENTS?

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Learning to Use Bifocals

By Don Casada and John Kueck, Oak Ridge National Laboratory (ORNL)

Both of the authors of this article are learning to use bifocal glasses. The general idea with bifocals is that they provide two general zones of focus—the lower portion for close up (e.g., reading) and the upper for distance. Leaning your head back while driving or looking out the bottom part of your glasses while descending stairs are recipes for disaster.

There are many demerits associated with our condition (not the least of which are egotistical factors), but like most of life's difficulties, the lessons we learn here have analogs in other arenas.

Take the case of adjustable speed drives, for example. We'd like to discuss two common aspects of drives from a couple of different focal lengths.

Efficiency or Power?

A common way of comparing device A with device B in the energy domain is to compare efficiencies. After all, efficiency is a sort of universal standard that is used in everything from hog farming to haute cuisine, defining the value of the product in proportion to the cost of the input.

Figure 1 shows typical combined drive and motor[1] efficiencies for a new, pulse-width-modulated (PWM) drive and an older eddy-current (EC) drive when connected to a centrifugal load, such as a pump or fan. There is obviously a dramatic difference in drive efficiency at reduced speeds.

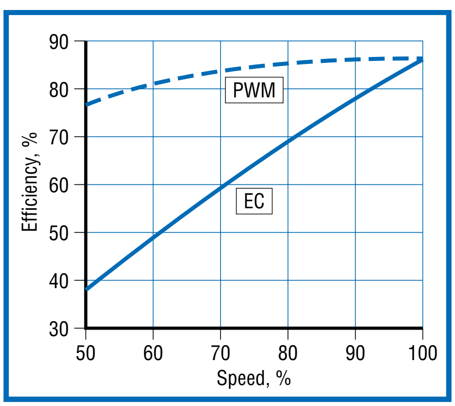


Figure 1. Combined motor and drive efficiency vs. speed.

Consider a situation where we have a fan load that operates at full speed 75% of the time and at half speed 25% of the time. Table 1 shows the combined motor and drive efficiencies at those speeds and calculates an average efficiency.

Table 1. Motor and Drive Efficiency Comparison

Drive Type	*Full-speed efficiency*	*Half-speed efficiency*	*Average efficiency[2]*
PWM	86%	77%	84%
EC	86%	38%	74%

The average electromechanical efficiency with the EC drive is only 88% of that with the PWM drive, certainly a noteworthy difference.

Now let's extend our point of focus to include the electric meter. Does our electric bill include an average efficiency term? Of course not—we pay for energy[3]. Let's assume that the fan requires 50-hp shaft output power at full speed and behaves according to the centrifugal load affinity laws (flow rate is proportional to speed, and power is proportional to the speed cubed). For this assumed load, the electric input power vs. speed shown in Figure 2 applies.

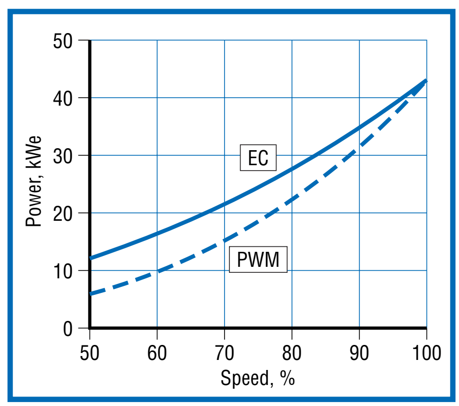


Figure 2. Electric power vs. speed.

(continued on page 7)

Guest Column

Using ASDs with Variable Torque Applications

By John Malinowski, Baldor Electric Company, Fort Smith, AR

Operating energy costs continue to be a major concern for plant managers. Recent studies of electric motor applications show that pumps require 31% of the energy used, 18% for compressors, 18% for blowers and fans, and about 14% for conveyors.

Variable torque applications are the best candidates for adding an adjustable speed drive (ASD) to save energy. Centrifugal pumps and fans are variable torque loads where the amount of power required drops off by the cube of the speed decrease. Thus, the actual savings come from reducing the motor speed, resulting in lowering the motor's power requirements. Constant torque applications such as conveyors often use ASDs, but generally this is not for reasons of energy savings, rather it is for production flow improvements.

Let's look at a pump application with varying flow requirements. Typically, control valves are used to regulate flow from a pump with the motor and pump operating at fixed speed with the motor driven directly from the power line. As the valve is closed, the amount of energy that is wasted is increased. If instead of throttling, an AC inverter (a type of ASD) is employed, considerable savings can be achieved. To illustrate, assume we have a centrifugal pump that requires 100 hp at design flow. Let's further assume an electrical cost rate of $0.07/kWh, an equipment and installation cost of $8,800, and required flow rate that varies from 40% to 90% of design capacity, per Table 1.

Table 1. Load Profile

% of flow rate	*% of year*
40	10
50	20
60	40
70	15
80	10
90	5

As shown in Figure 1, the purchase and installation costs would be recovered from energy savings in less than 5 months, with annual savings of about $22,000.

Caution needs to be taken in this inverter retrofit. Inverters not only reduce the speed by adjusting the voltage and frequency, the motor can also be made to operate above its base speed. Since horsepower requirements on a centrifugal pump increase by the cube of the speed change, it doesn't take much more speed to overload the motor and risk premature failure.

Operation of an AC induction motor from a pulse-width-modulated (PWM) inverter causes extra motor heating due to harmonics. The signal of the inverter to the motor is an artificial sine wave. Motors operating from inverters may experience extra heating resulting in premature failure. Newer high efficiency (EPAct) and premium efficiency motors often have low temperature rise. A rule of thumb is that for every 10°C cooler a motor operates, its insulation life is doubled. Newer motors will also have insulation capable of handling the higher temperatures at which the motor operates when powered from an inverter. Many new motors have a Class F (155°C) insulation system whereas older motors may only be Class B (130°C). Most *inverter-ready* motors have a Class H system rated for 180°C operation.

Although the inverter will operate any three-phase AC induction motor, it is wise to purchase a motor with an insulation system that will handle the troublesome voltage spikes, which may be 1600 volts or more in applications with long motor-feeder cables. New inverter spike-resistant magnet wire provide more than 100 times more resistance to high-voltage spikes than standard magnet wire. Long wiring runs between the motor and inverter increase the high-voltage spikes by a condition called "voltage ring-up". To mitigate this situation, line reactors or harmonic filters can be placed between the motor and control.

NEMA addresses operation of inverter-fed motors in its MG 1-1998 standards. Part 31 discusses specific-purpose motors for inverter-fed power supplies. It would be wise to select a motor that complies to MG 1-1998, Part 31.4.4.2 for voltage spikes as a minimum requirement.

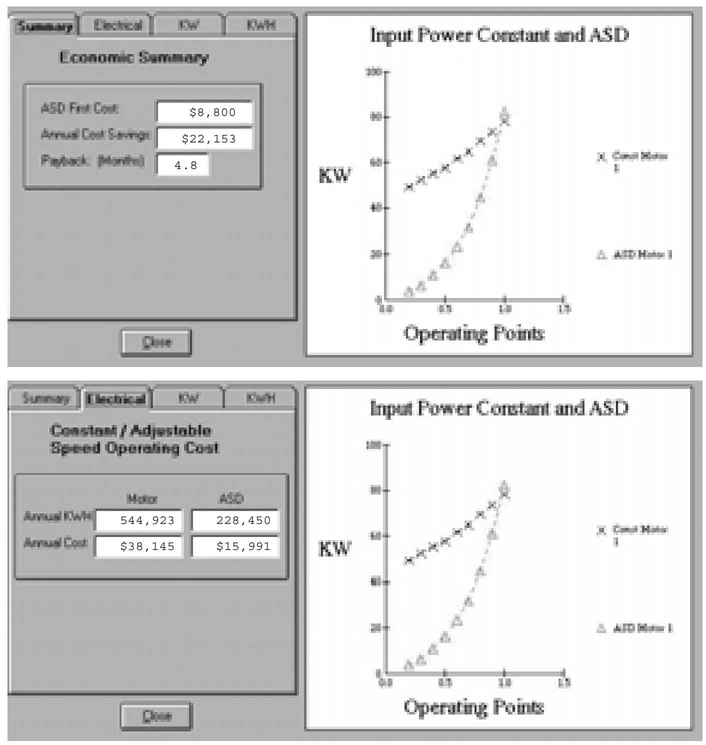


Figure 1. On variable torque applications, ASDs can offer significant energy savings and quick payback periods.

Addition of inverters to power motors may provide reduced maintenance and production improvements as well. Instead of starting the motor across the line, the inverter will "soft-start" the motor. By increasing the speed gradually, mechanical stresses on the motor, pump, couplings, and pipes are reduced. Any water hammer (heard as a banging noise in the piping system) should be eliminated. If required, the inverter speed may be adjusted automatically via a process control loop, providing a more precise flow of water from the pump as required by the production process.

(continued on page 4)

Guest Column

continued from page 3

Since most variable torque applications are similar, HVAC installations offer similar savings.

Constant torque applications such as conveyors don't offer the same energy savings as variable torque applications because power is only linear with speed. Again production improvements may be seen with the addition of ASDs. Changing out older, less efficient motors to current premium efficiency designs will reduce energy usage.

Many older conveyors are already adjustable speed, but powered by DC motors and SCR (thyristor) controls. Typically these DC drive systems have efficiencies in the 80-85% range compared to newer AC drives with efficiencies in the mid-90s. Power factor on DC drives may be in the 50% range whereas power factor for AC drives is approaching unity. Changing an older DC SCR system to an AC Vector Drive can provide better performance than the old DC drive. The AC Vector with encoder feedback can provide constant torque from base speed all the way to zero speed. Besides the energy savings, the maintenance required by the brushes and commutator of the DC motor is eliminated (downtime and costs). A larger motor is sometimes required for low-speed, constant-torque applications.

Energy savings translate directly to the bottom line of any manufacturing facility. All of these technologies are proven, in use for 10 years or more. Many different suppliers build inverters, vector drives, and inverter-ready motors. Most difficulties encountered are simple and easily resolved.

Local distributors can help estimate savings and initial investment in equipment costs. Most manufacturers also have free cost/analysis software available to help calculate these savings. These computer programs calculate payback details based on the actual motors you have in your plant, duty cycles, and energy costs.

For questions or comments, contact John Malinowski at (501) 648-5909 or send e-mail to John_Malinowski@baldor.com.

Performance Optimization Tips

Field Measurements in Pumping Systems—Practicalities and Pitfalls

By Don Casada, BestPractices Motor Systems, Oak Ridge National Laboratory

This article is the 4th in a series dealing with practical considerations and pitfalls of field measurements needed to understand pumping systems.

One by one, we're addressing the individual elements critical to understanding pumping system operation. But remember the importance of maintaining a system perspective, not just elements in isolation. In the words of Robert Browning (from A Grammarian's Funeral):

"Image the whole, then execute the parts—
Fancy the fabric
Quite, ere you build, ere steel strike fire from quartz,
Ere mortar dab brick!"

Does Your Car Have a Speedometer?

I recently led a PSAT[1] workshop, and we discussed a scenario where no flow instrumentation was installed. Tom Angle, Director of Technology for Envirotech Pump, offered this insightful simile: "A pumping system without a flow meter is like a car without a speedometer."

Tom further noted that we wouldn't buy a car without a speedometer, but we routinely see pumping systems without flow meters. To see how out of whack this is, let's do an operating cost comparison between a mid-size car and a small industrial pump.

Energy Cost Comparison

	Automobile	*25-hp pump*
Fuel unit cost	$1.40/gallon	5 ¢/kWh
Annual usage	15,000 miles	6,132 hours
Power source effectiveness	25 miles per gallon	93% (motor efficiency)
Annual cost	$840	$6,150

Quite a contrast! If I doubled the gas mileage of my automobile to 50 miles per gallon, I'd save only a third of what I'd save if I dropped my pump load from 25 down to 20 horsepower. Doubling my car's gas mileage would be a challenge, but a 20% improvement is often achievable in pumping systems—if system performance and requirements are well understood.

I suspect that 99% of the time you use your speedometer simply to avoid getting the "blue light special." Consider how big a fine you pay to the local electric utility every day because you don't know your pumping system's speed.

I'm Appalled—No Meter's Installed!

Pumping systems with no flow meters are very common, even in large industrial systems. Because energy costs usually overwhelm capital costs for pumping systems, the wisdom of building an unmetered system may be questionable. But given this reality, we'll identify alternative approaches to estimating flow rate in such systems[2]. Beginning with this issue, we'll discuss three methods:

1) Use of head-capacity curve.
2) Volume change rate measurement.
3) Velocity head deduction.

As we begin to discuss these techniques, here is one final automobile analogy.

With my car on cruise control, I occasionally compare my odometer-indicated distance and speedometer-indicated speed with the distance and speed deduced from mileage markers and my wristwatch. Doing this, I can verify that my speed and mileage indications are reasonably accurate (assuming that my watch and the mileage markers are dependable).

Similarly, these flow-estimating techniques, though far from perfect, are worth considering, *even when a flow meter is installed.*

(continued on page 5)

continued from page 4

Using the Head-Capacity Curve

Pump manufacturers develop head-capacity curves for generic pump models, based on test performance data. These curves are useful in selecting a pump for a particular service; they can also be used to estimate flow rate based on measured head.

Consider the pump configuration in Figure 1, and the head-capacity curve in Figure 2.

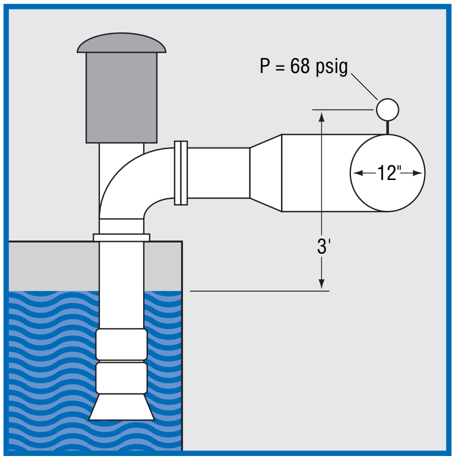


Figure 1. Example pump configuration.

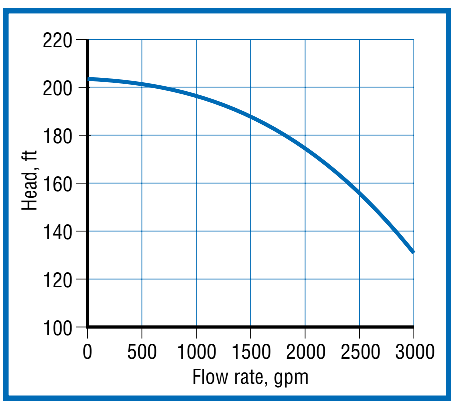


Figure 2. Generic head-capacity curve (1750 rpm).

If this system is handling ambient temperature water, the 68-psig discharge pressure and the 3-ft elevation difference from the vented suction tank to the discharge pressure gauge equates to a developed head difference of about 160 ft. From Figure 2, the flow rate deduced would be about 2400 gpm.

Pretty straightforward, right?

But What About?…

Now let's flag a few assumptions inherent in this approach:

1) This pump's original performance curve is identical to the generic curve.
2) The field performance is identical to the test facility performance.
3) Pump performance is not degraded from service wear or foreign material.
4) The actual rotating speed is 1750 rpm.

How many of these assumptions are likely to be valid?

For the first assumption, consider the Hydraulic Institute's (HI) acceptance test tolerances for a pump in this general category[3], which allows the measured head to be up to 8% above that specified at the rated flow rate. Alternatively, the flow rate can be up to 10% above that specified at the rated head. This tolerance range alone gives an indication of the potential variability from pump to pump, and highlights the value of a certified test curve for the specific pump.

Field and test facility performance can differ for a variety of reasons; in this example, the discharge pressure is measured downstream of an expander and discharge header tee. There are losses across these components that would need to be accounted for.

The potential effects of service wear can be extremely variable, but the longer a pump has been in service, the less likely it will perform like new.

Fortunately, speed equality can be checked (for example, with a strobe light as shown in Figure 3) and accounted for, if different. We'll illustrate how speed can be accounted for with ASDs. This is important, even when operating on a fixed speed motor.

Figure 3. Strobing pump shaft speed.

Assume we find the rotational speed of the pump is 1780 rpm. Using pump affinity laws, the head-capacity curve can be adjusted upwards, as in Figure 4.

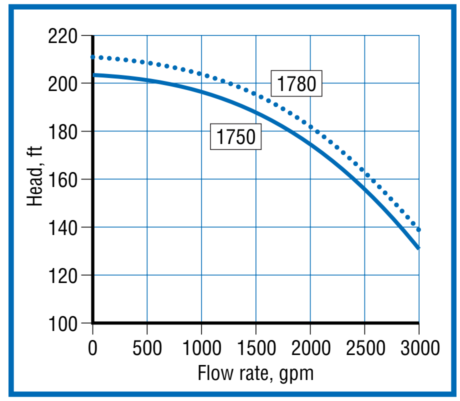


Figure 4. Head-capacity curves for 1750 rpm and 1780 rpm.

The flow rate at 160 ft on the 1780 rpm curve is 2570 gpm, about 7% more than estimated from the 1750 rpm curve. If the measured head had been 200 ft, the speed-related error would be dramatically greater—over 75% (700 vs. 1240 gpm)!

One last potential "gotcha" in using pump head to estimate flow rate is that the velocity head component must be included. But since the velocity head can only be determined once the flow rate is known, we must use an iterative solution[4]. In this case, the velocity head component is small (about 0.7 ft), but that is not always the case.

In the next issue, we will cover the other two methods of estimating flow rate in unmetered systems.

Comments/questions welcome by e-mail: a85@ornl.gov

1 PSAT– Pumping System Assessment Tool, a DOE software product available as a free download at: http://public.ornl.gov/psat.

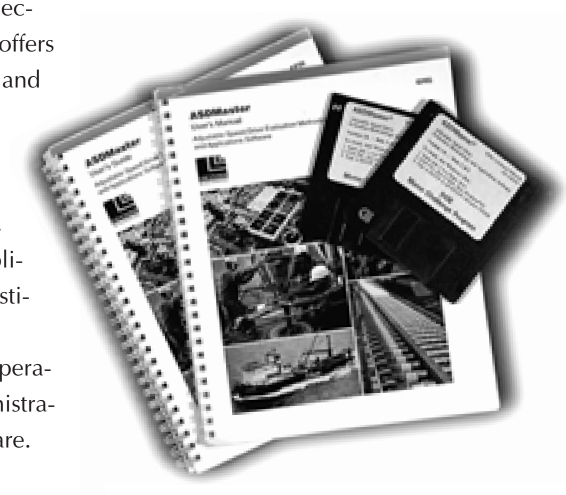
2 Clamp-on, ultrasonic flow meters are available that are non-intrusive. My experience with externally mounted ultrasonic meters has been mixed. I'm not aware of a report on independent testing of such flow meters under real-world conditions, but encourage readers to provide feedback in this regard.

3 See ANSI/HI 2.6-1994, Vertical Pump Tests, Section 2.6.5.3.

4 There is a way to avoid the iteration – but we'll leave that for a future column.

Maximize Your ASD Application with ASDMaster

Control of process equipment using electronic adjustable speed drives (ASDs) offers significant opportunity to save energy and improve operations. However, the effects of ASDs on process systems are not always well understood. To simplify the process of learning about, analyzing, and specifying an ASD application, the Electric Power Research Institute (EPRI) Adjustable Speed Drive Demonstration Office (ASDO), in cooperation with the Bonneville Power Administration, developed the ASDMaster software. Designed with the layperson in mind, ASDMaster provides a suite of educational materials and software tools for people with little or no experience applying ASDs, to experienced ASD application engineers looking for accurate, user friendly analysis software.



How Does it Work?

ASDMaster is a windows-based software package consisting of six different modules designed to educate and assist users in the proper application of ASDs. A software instruction module and text are included to educate users on the process effects, technology, and power quality issues associated with ASDs. Analysis tools assist users in the accurate, total systems-based analysis of the energy and production benefits associated with ASDs. A simultaneous analysis is performed on constant speed controls for comparison. ASDMaster also contains a specification tool that assists users in writing a solid performance specification for an ASD, just by answering the appropriate questions and filling in the blanks. Finally, ASDMaster's database module directs users to manufacturers with ASDs that can meet their needs, generating a bid-list and contact information with just a few button-clicks.

Where to Get Your Copy

To order your copy of ASDMaster, or to receive more information about the product, call the EPRI ASDO today at 1-800-982-9294.

Adjustable Speed Drive Application Workshops

If you are an end user, utility, or motor manufacturer, the Adjustable Speed Drive Application workshops can help you in your job. These workshops address the fundamentals of ASDs and offer a demonstration of the ASDMaster software. The workshops are offered in co-sponsorship with OIT Allied Partners.

Attend one of the following:

- April 25 in Marlboro, MA, MA Toxics Use Reduction Institute.

  Call Ann Berlin Blackman at (978) 934-2124.
- May 9 in Greensburg, PA, PA DEP Allegheny Power.
- May 23 in Manchester, NH, State of NH Wastecap Resource Conservation Network.

  Call Erin Wheeler at (360) 754-1097, ext.104.

Soliciting Help

OIT's Industrial Assessment Center (IAC) program is soliciting ABET accredited engineering schools across the country to help small and medium size manufacturers save money and improve productivity. The Industrial Assessment Centers, at present, are located at 30 universities across the country. Teams of engineering faculty and students from the centers conduct, at no cost, industrial assessments and provide recommendations to small and medium size manufacturers to help them identify opportunities to improve productivity, reduce waste, and save energy. Recommendations from industrial assessments have averaged about $55,000 in potential annual savings for these manufacturers.

Solicitations will be sent to the Department Heads and Deans of Engineering at all ABET accredited schools. Call Gwen Looby at (215) 387-1535, ext. 221, for more information.

Mark Your Calendar for…

…the 4th OIT Industrial Energy Efficiency Symposium and Exposition. Set for February 19-22 in 2001, this event will help U.S. industry prepare to compete globally. Learn from recognized experts who will share their perspectives on the competitive challenges awaiting U.S. manufacturers and hear their potential solutions for success in global markets. The exhibit hall will feature over 150 booths highlighting technologies under development, emerging cutting-edge processes, and other results of collaborative partnerships. Join other manufacturers, government R&D managers, corporate R&D directors, university researchers, national laboratory scientists, representatives from the financial community and many more at this exciting Expo, to be held in Washington, D.C.

How to Register

You may register online at www.oitexpo4.com or call (877) OIT-7967 to obtain a registration form.

Learning to Use Bifocals

continued from page 2

Table 2 shows the power for the two load conditions, and annual electrical energy and expense, assuming an energy cost of $.05/kWh.

Table 2. Power, Energy, and Cost Comparison

Drive Type	*Full-speed kWe*	*Half-speed kWe*	*Annual MWh*	*Annual cost, $1000*
PWM	43	6	296	$14.8
EC	43	12	309	$15.4

The energy consumed by the PWM drive is only 4% less than the EC drive. Why is this? The simple reason is that the affinity laws are the dominant factor—the shaft power required at 50% fan speed is only 1/8 of what it was at full speed. With this load profile, it would be very difficult to justify replacing a functional, less efficient EC drive with a new PWM drive. A different conclusion might be reached with a different load profile; the point is that efficiency comparisons don't tell the whole story.

Beyond the Affinity Laws

Now that we've shown why the affinity laws tend to dominate the picture in centrifugal loads, it is worth extending our focal length a bit more to see a system picture. A very common mistake made in developing rough estimates of energy reduction by applying adjustable speed drives is to simply use the affinity laws.

Assume we have a pump that is operated simply to fill a tank. The tank supplies the system (by gravity) continuously, but the pump only has to run 12 hours a day to keep the tank full. According to the affinity laws, if we slowed the pump down to 50% speed, the flow rate would drop to half and the power would drop by a factor of eight. If we ran the pump at half speed for 24 hours a day instead of at full speed for 12 hours a day, the energy consumption would go down by a factor of four, right? *Wrong.*

If the system had *no* static head, the logic would be fine; but in many pumping systems, static head is a significant part of the overall system head. For example, as shown in Figure 3, the pump operates at about 3350 gpm and 50 ft of head when operated at full speed. However, when it is slowed to half speed, the flow rate is 0 gpm; in other words, the pump function has switched from a water mover to a water heater. The simple reason is that the system has static head—in this case, about half of the head at full speed is static.

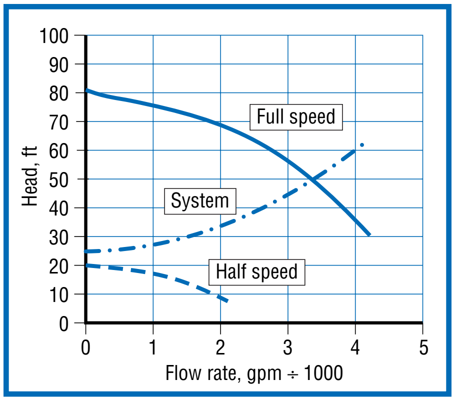


Figure 3. Electric power vs. speed.

Looking Out the Top of the Lens

In many industrial operations, adjustable speed drives can be beneficial. There are many details that must be considered in implementing drives. But these examples have illustrated how too narrow a focus on individual component performance and the failure to see the system as a whole can lead to significant errors.

While the examples used here are just that—examples—they are in their essentials identical to situations that are commonly encountered. Don't be misled by the details—look out the upper part of the lens and see the system as a whole.

[1] The PWM data for Figure 1 is average performance of three drives tested with an older, standard efficiency, 50-hp motor at ORNL. The eddy current efficiency curve assumes 3% loss at all speeds combined with measured direct, across-the-line efficiency for the same motor (full-load motor efficiency was 89%).

[2] Weighted according to the percentage of time operated at the two speeds.

[3] Some electric billing structures also include demand charges and/or power factor penalties; PWM drives do improve power factor.

Letters to the Editor

Energy Matters welcomes your typewritten letters and e-mails. Please include your full name, address, association, and phone number, and limit comments to 200 words. Address correspondence to:

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Golden, CO 80401
e-mail: michelle_sosa-mallory@nrel.gov

We publish letters of interest to our readers on related technical topics, comments, or criticisms/corrections of a technical nature. Preference is given to letters relating to articles that appeared in the previous two issues. Letters may be edited for clarity, length, and style.

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ENERGY MATTERS EXTRA
MORE COVERAGE OF ENERGY EFFICIENCY OPPORTUNITIES FOR YOUR INDUSTRY

Find more articles and resources on this issue's theme—ASD Technologies—by visiting the Energy Matters Extra Web site. From here, you can also link to a Web-based Combined Heat and Power (CHP) analysis tool to screen a potential CHP site. Then, access the Office of Industrial Technologies' (OIT's) new online discussion database to post your comments or questions about CHP. Universities will find a new solicitation announcement with the details on applying for participation in OIT's Industrial Assessment Center program. **Go to Energy Matters Extra at www.motor.doe.gov/emextra.**

Naming Names

David Gaw of the Washington State University Energy Program took the Name Game Challenge (November/ December issue of Energy Matters Extra) and correctly identified 19 of the 25 historical energy champions hidden within a story by Don Casada. Our thanks and congratulations to Mr. Gaw for his effort. Check out the answers in the current edition of Energy Matters Extra—and watch for other energy-related quizzes in future editions.

Coming Events

Fundamentals of Compressed Air Systems

- April 19, in Northhampton, MA, New England Electric, MA Electric.

Call Anita Hagspiel at (508) 421-7221.

Adjustable Speed Drive Application Training

- April 25 in Marlboro, MA, MA Toxics Use Reduction Institute.

Call Ann Berlin Blackman at (978) 934-2124.

- May 9 in Greensburg, PA, PA DEP Allegheny Power.
- May 23 in Manchester, NH, State of NH Wastecap Resource Conservation Network.

Call Erin Wheeler at (360) 754-1097, ext.104.

Pump Systems/Pumping System Assessment Tool Workshop

- April 26 in Marlboro, MA, MA Toxics Use Reduction Institute.

Call Ann Berlin Blackman at (978) 934-2124.

- May 1 in Westbrook, CT, BJM Corp.

Call Anna Maksimova at (360) 754-1097, ext. 100.

NC State University, Industrial Extension Service Workshops

- Cooling Tower Operations, April 25 in Atlantic Beach, NC.
- Energy-Efficient Lighting, April 26 in Atlantic Beach, NC.
- Preventive Maintenance, April 27 in Atlantic Beach, NC.
- Energy-Efficient Motors, May 5 in Atlantic Beach, NC.
- Certified Energy Manager, May 8-9 in Raleigh, NC. (2 days, 8:30 a.m.-4:00 p.m.)

All events last from 9:00 a.m. till 4:00 p.m. For more information, contact Jim Parker at (919) 515-5438, or at jim_parker@ncsu.edu.

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Information Clearinghouse

Do you have questions about using energy-efficient process and utility systems in your industrial facility? Call the OIT Information Clearinghouse for answers, Monday through Friday 9:00 a.m. to 8:00 p.m. (EST).

HOTLINE: (800) 862-2086

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